



MARS INSTITUTE



Phobos and Deimos

Planetary Protection Knowledge Gaps for Human Missions

Pascal Lee^{1,2,3} and Kira Lorber¹

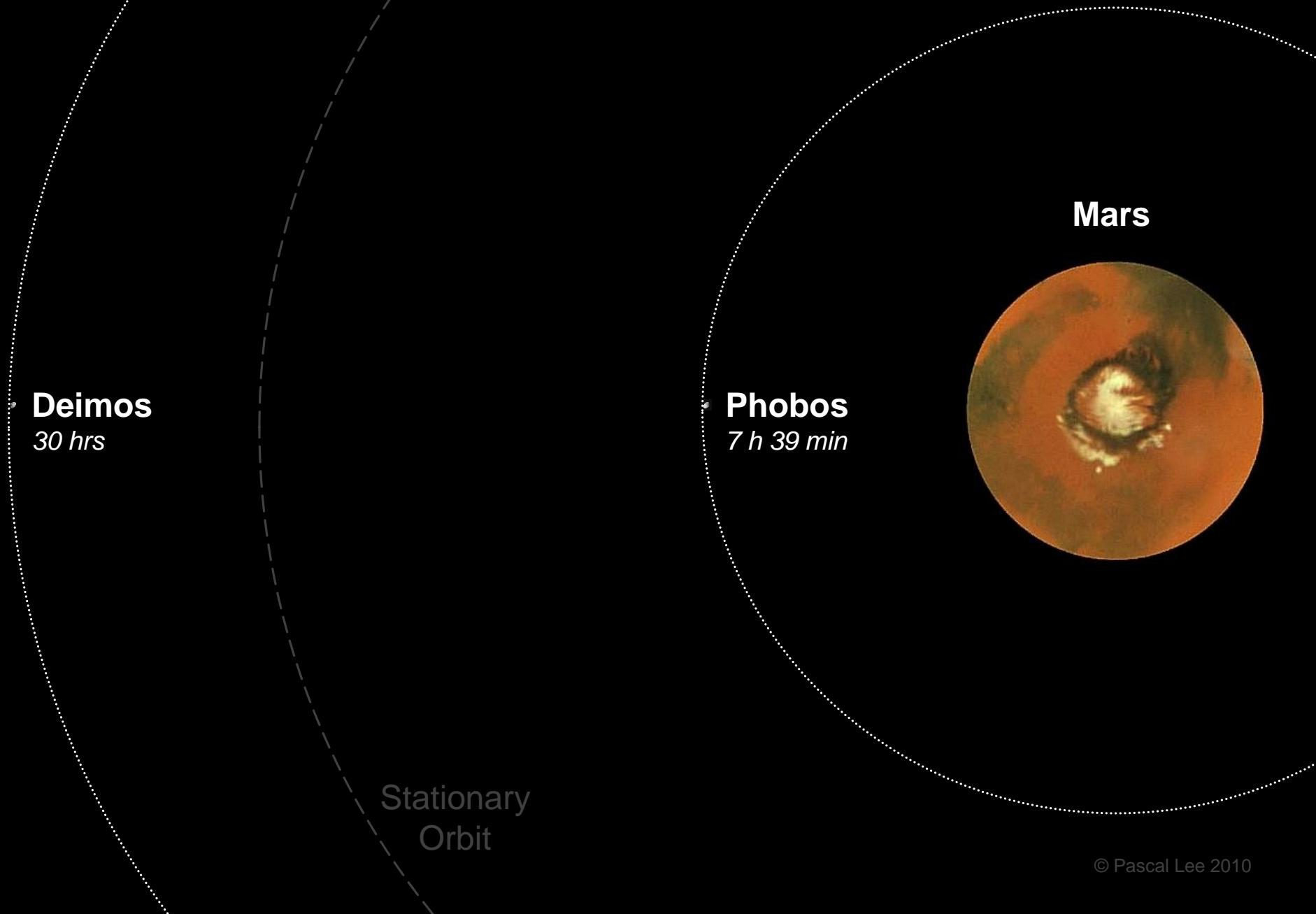
¹ *Mars Institute*, ² *SETI Institute*, ³ *NASA Ames Research Center*

Workshop on Planetary Protection Knowledge Gaps
for Human Extraterrestrial Missions
NASA ARC, 24-26 March 2015

Outline

- Phobos & Deimos: General
- Phobos & Deimos: H₂O + Other Volatiles
- Phobos & Deimos: Closing PP KGs

Phobos and Deimos: Orbits



Phobos: Orbit

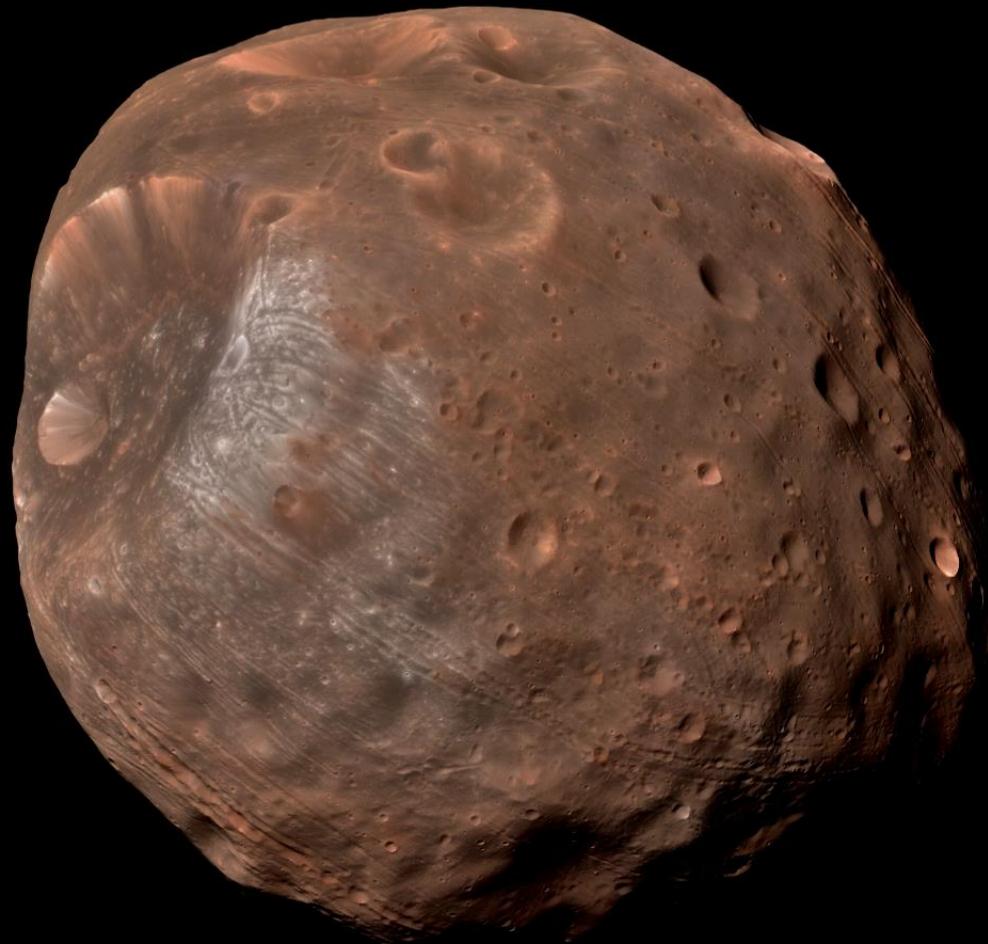
Phobos



Phobos and Deimos



Deimos



Phobos

Scale



Asteroid Itokawa



540 m



International
Space Station

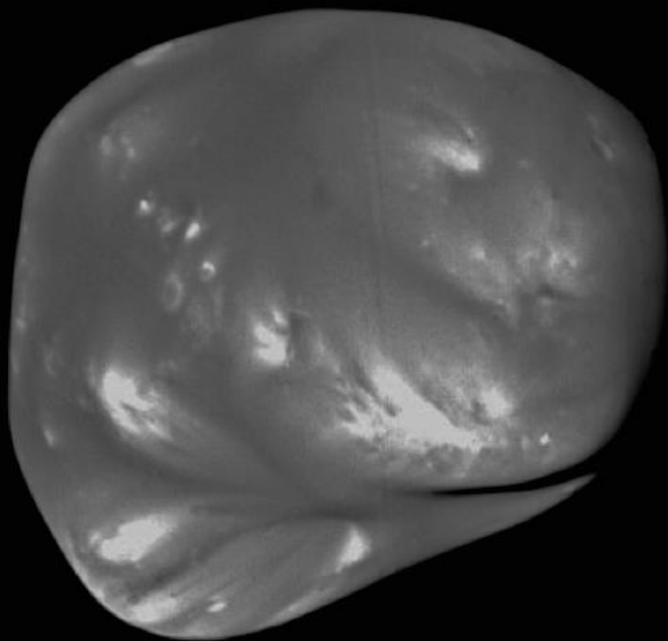


80 m

Scale

Itokawa

ISS



Deimos



Phobos

Phobos & Deimos: General

- Two (Known) Moons of Mars
- Discovered by Asaph Hall in Aug 1877
- Observed Opportunistically by Several Spacecraft
Viking Orbiters, Mars Pathfinder, MGS, MRO, Mars Express, Rosetta
- 3 Dedicated Missions: All Failed at Primary Objectives
Phobos 1 & 2 (USSR), Phobos-Grunt (Russia)
- Future Missions?
 - 2020: PADME (Proposed NASA Discovery Mission)
 - 2025: BOOMERANG (Russia) / PHOOTPRINT (ESA) SRM
 - 2025-29: NASA ROBOTIC PRECURSOR (Lander/SRM)?
 - 2035: HUMAN MISSIONS TO MARS ORBIT

Phobos & Deimos: Potential

Science

- Primitive vs Evolved Small Bodies
- Mars Archive: Regolith Repository of Mars Impact Ejecta

Robotic Exploration

- Natural Observation Platforms in Mars Orbit
- Mars Sample Return Caching/Quarantining
- SRM and ARM Targets

Human Exploration

- Opportunistic Exploration Targets at Mars
- Resources in Mars Orbit (H_2O , Metals, Rad Shielding)
- Consolidated Mars Sample Return
- Teleoperation of Robots on Mars w/o Time Delay

Phobos & Deimos: Origins

- **Hypothesis H1**
Captured Small Body from the Outer Main Belt or Beyond (OMBOB)



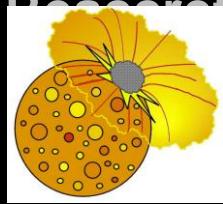
D-type Object Connection

Nice Model of Solar System Evolution – Origin of H₂O & Organics on E &

H₂O-rich Carbonaceous Chondrite-like

- **Hypothesis H2**

Recycled Mars Impact Ejecta



Mars Surface Connection

Satellite Formation by Giant Impact

Mars Crustal Rocks Minus Volatiles

- **Hypothesis H3**

Remnant of Mars' Formation



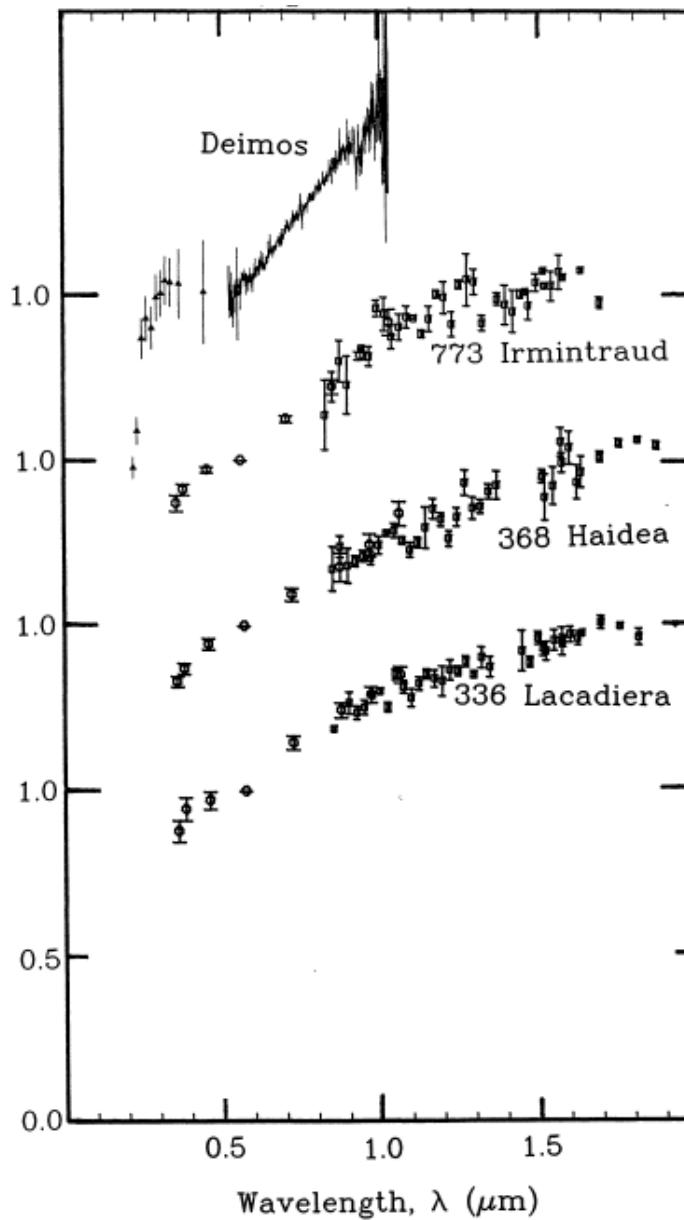
Mars Origin Connection

Terrestrial Planet Accretion – Origin of H₂O & Organics on Earth & Mars

Non H₂O-Rich Primitive Meteorites

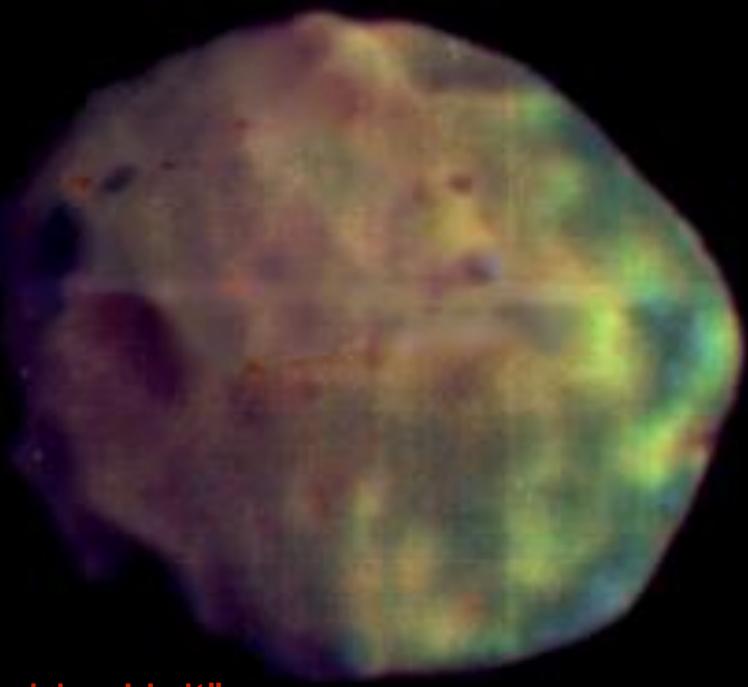
Deimos: D-Type Spectrum

Grundy & Fink 1991:
U of A Catalina Telescope



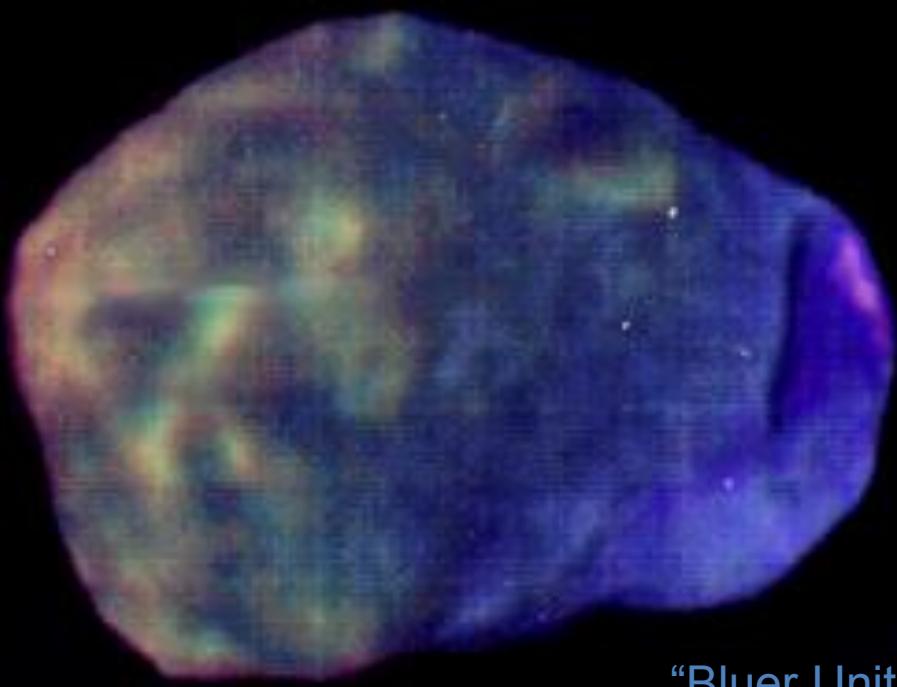
Phobos: “Redder” vs “Bluer” Units

Phobos 2 VSK Camera: Phobos Color Ratio Images



“Redder Unit”

~180°W



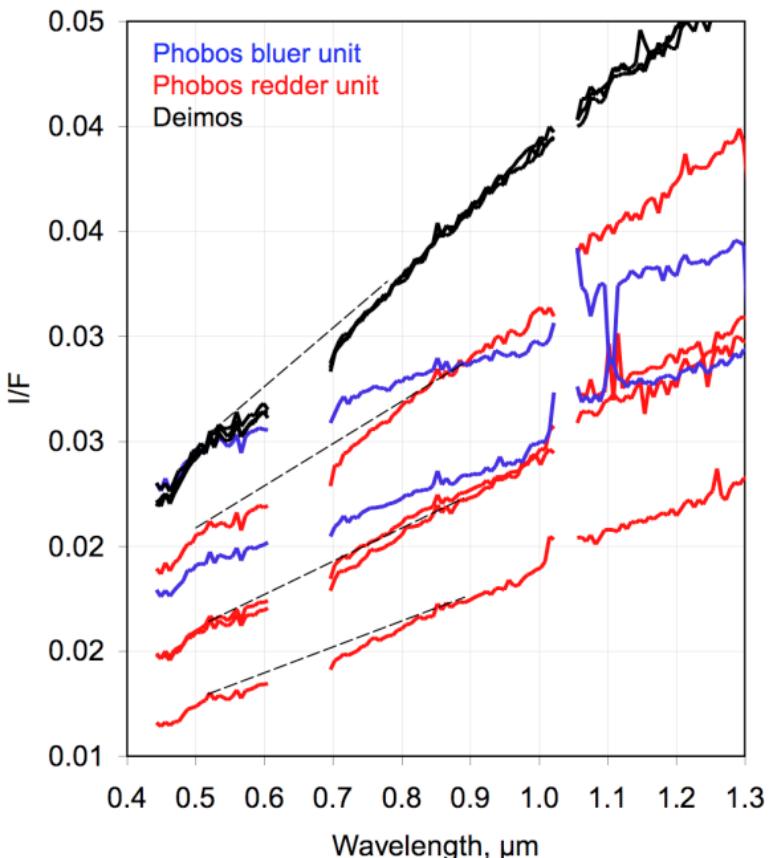
“Bluer Unit”

~120°W

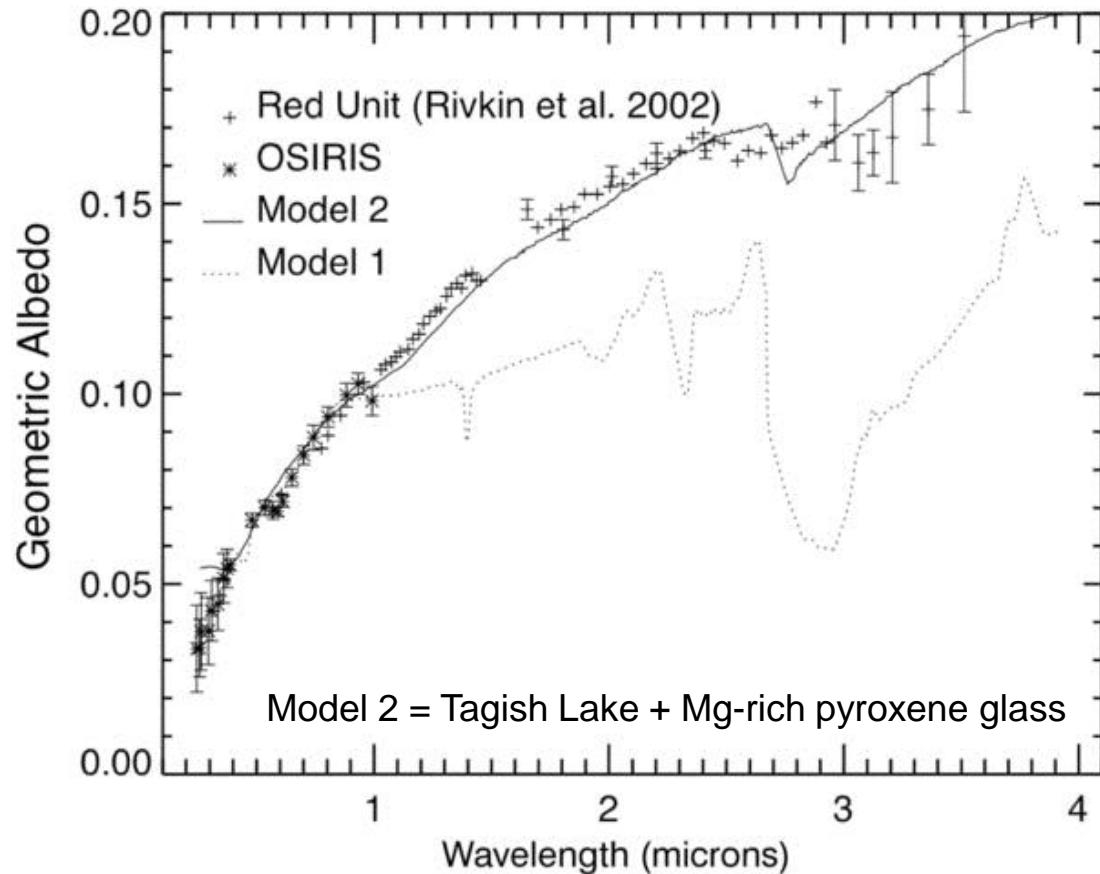
(Murchie et al. 1991)

Phobos: “Redder” vs “Bluer” Units

Phobos “Redder” Unit is D-type. So is the Tagish Lake Unusual CC Meteorite



MRO CRISM Data
Murchie et al. 2008

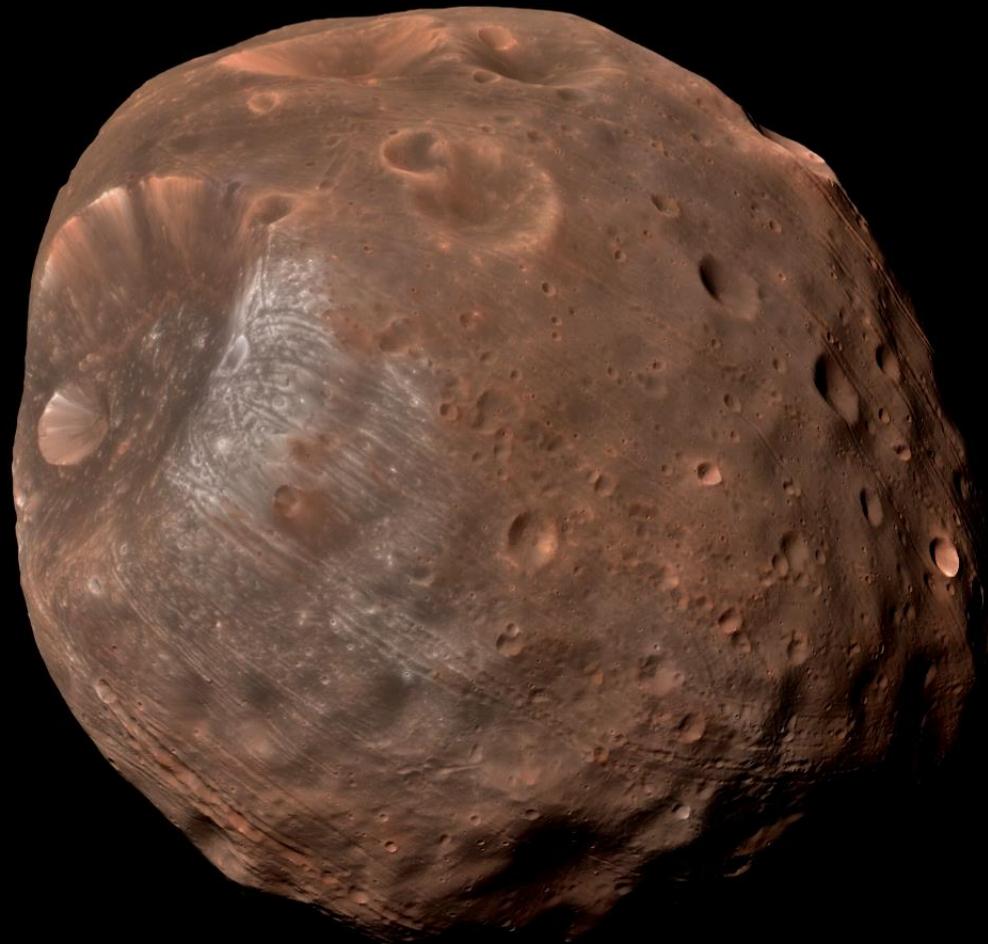


Rosetta OSIRIS
Pajola et al. 2013
+ Phobos 2 (Murchie & Erard 1996)
+ IRTF (Rivkin et al. 2002)

Phobos and Deimos

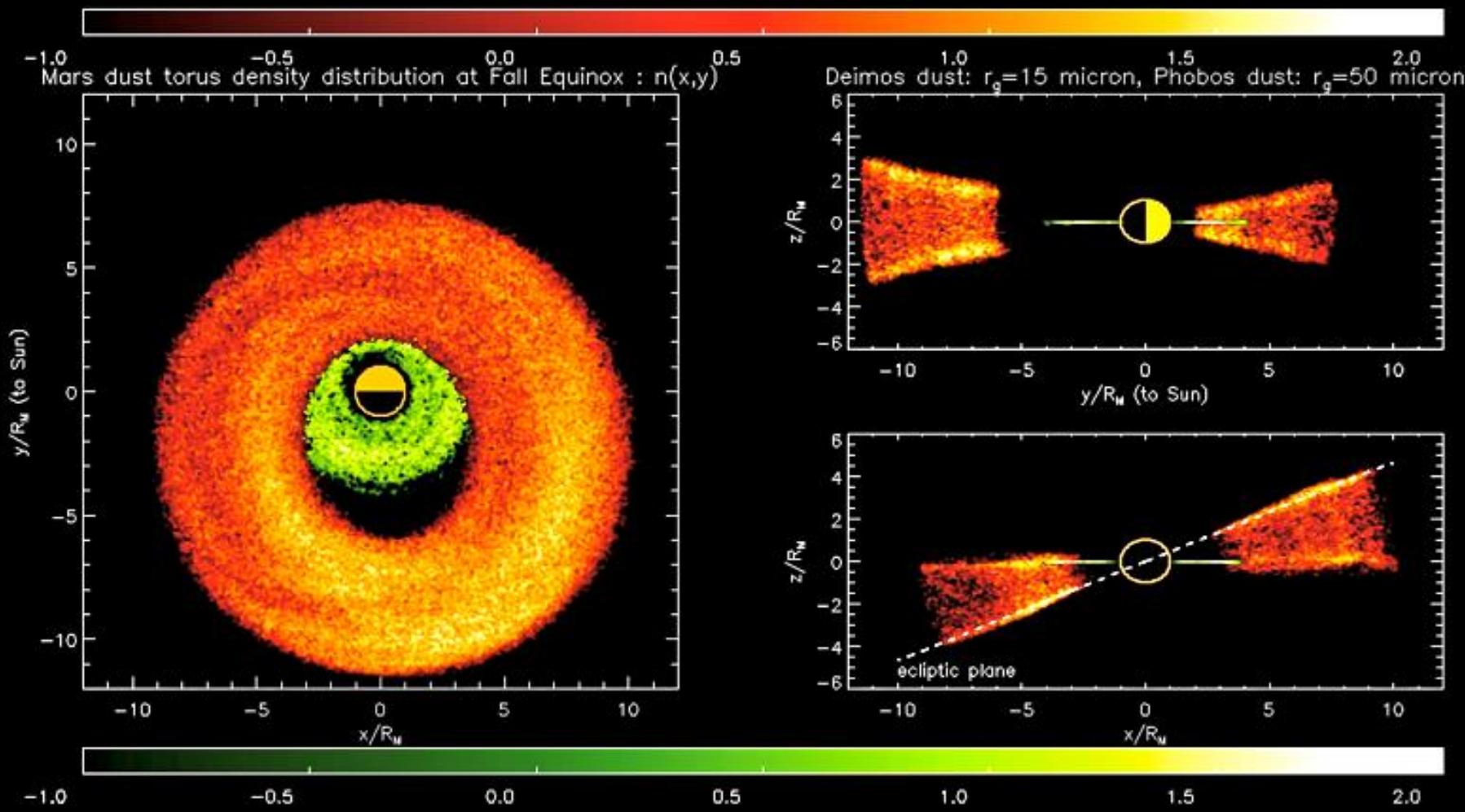


Deimos

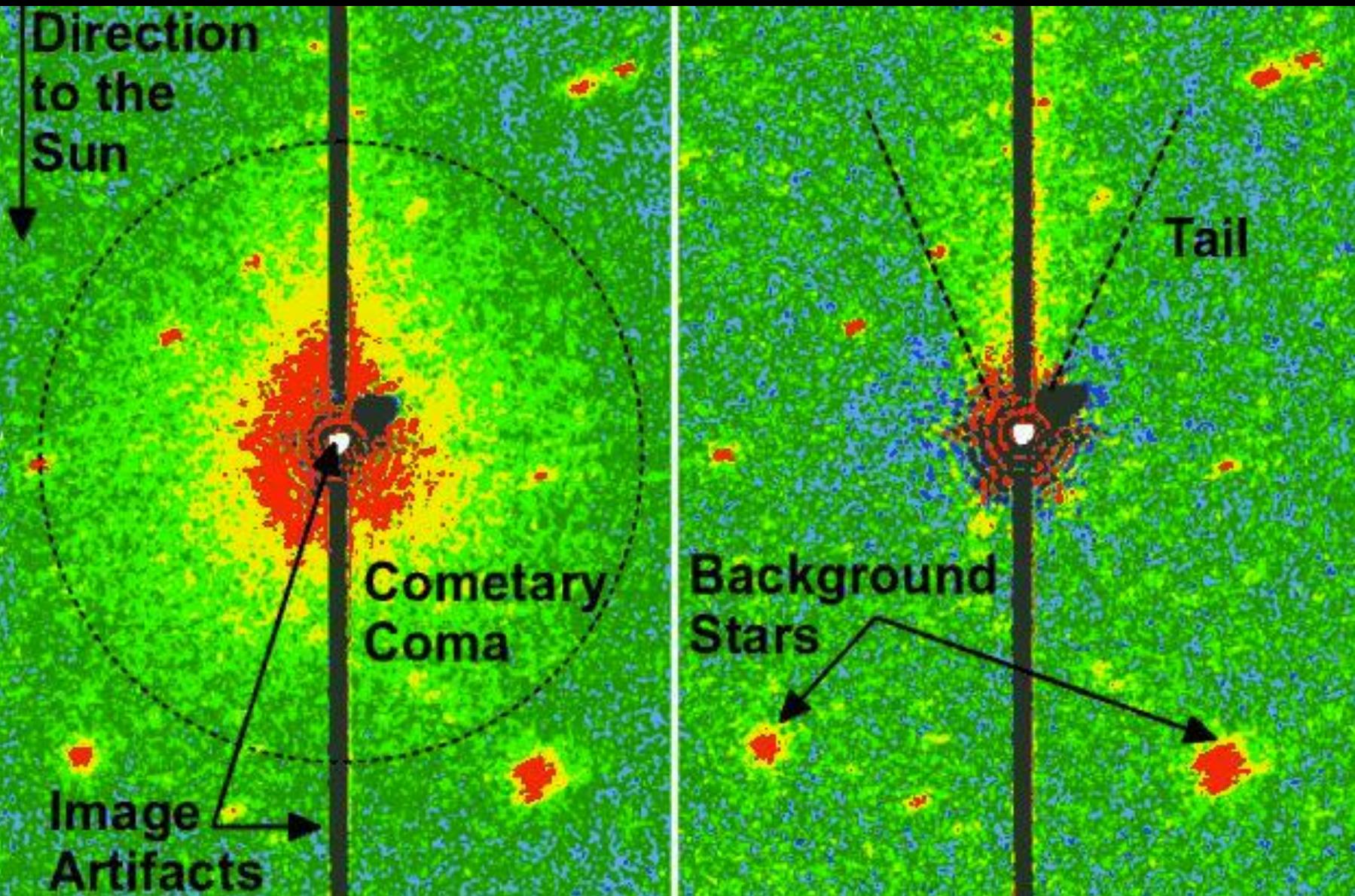


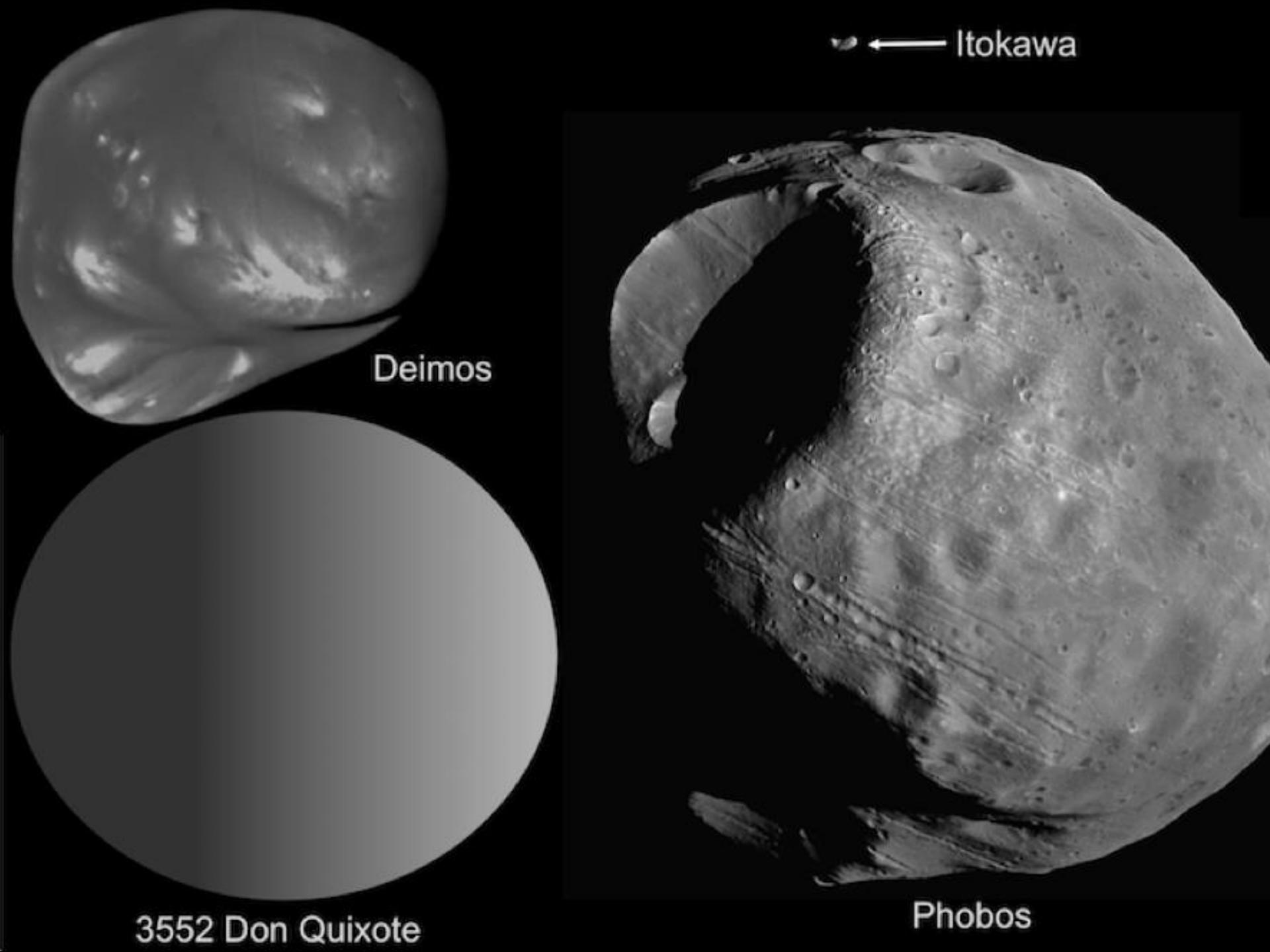
Phobos

Predicted Mars Dust Rings



D-Type 3552 Don Quixote





Itokawa

Deimos

3552 Don Quixote

Phobos

Phobos & Deimos: PP Knowledge Gaps

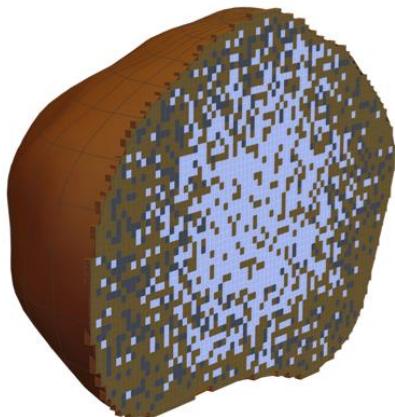
To Fill Major PP KGs, Need to Know **H₂O + Organics** Content,
i.e., Need to Constrain **Origin(s)**.

To Constrain Origin, Need to Know:

Surface Composition

Internal Structure

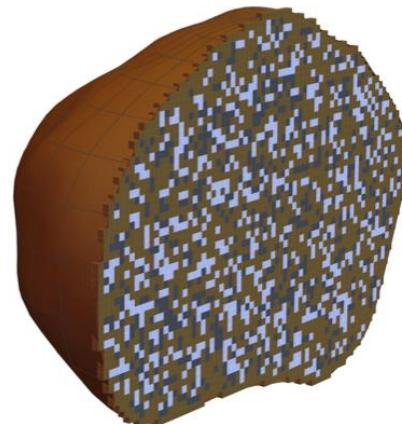
Dust Transport (esp. Deimos to Phobos)



Hypothesis H1

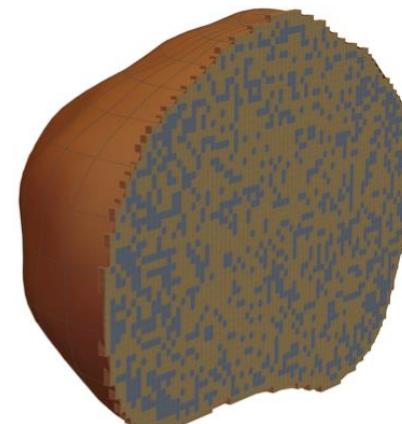
Rock: Primitive, H₂O-rich
Volatile-Rich

Heterogeneous



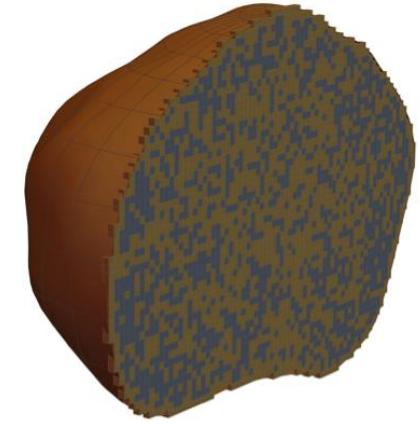
vs

Homogenous



Hypothesis H2

Rock: Mars Crustal
No Volatiles
Few Voids



Hypothesis H3

Rock: Primitive, H₂O-poor
Few Volatiles
Many Voids



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Phobos And Deimos & Mars Environment

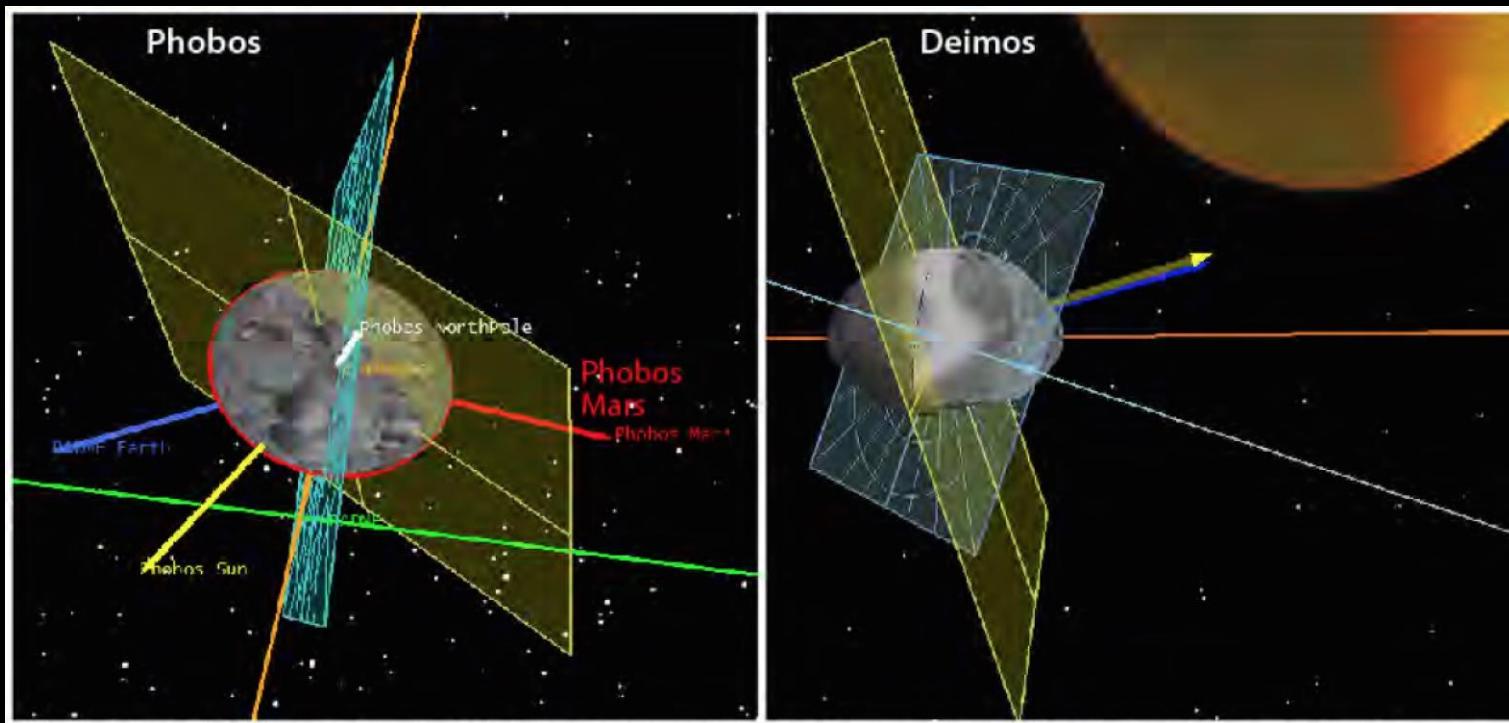


Important
Timely
Low Cost
Low Complexity
Exciting!

PADME

Multiple Close Flybys of Phobos and Deimos

- | | |
|---------------------|--|
| Surface Composition | ← Neutron Spectrometer + Mass Spectrometer |
| Internal Structure | ← Optical Imaging + Radio Science |
| Dust Dynamics | ← Optical Imaging + Dust Detection |



Phobos
16 flybys
C/A ~ 2 km AGL

Deimos
9 flybys
C/A ~ 2 km AGL

PADME

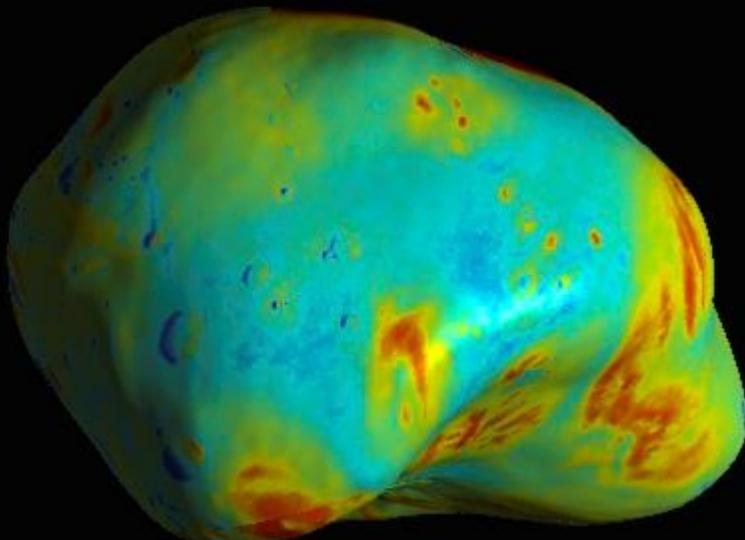
Mapping Surface Regolith Transport



Spatial Resolution

Color: **8 cm /pxl**

Monochromatic: **2.6 cm/pxl**

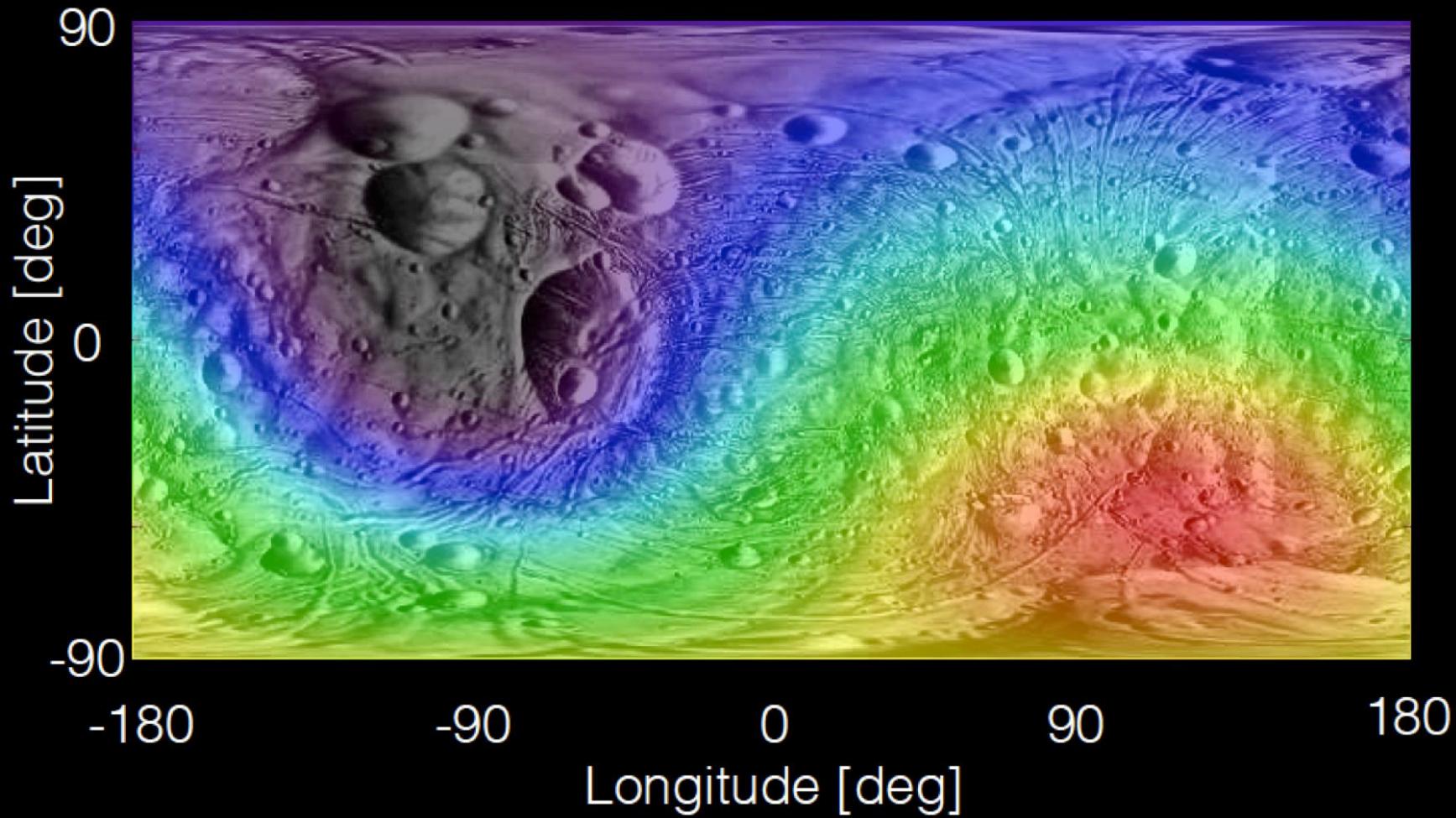


Mapping Dynamic Heights
Red: **Highs**
Blue: **Lows**

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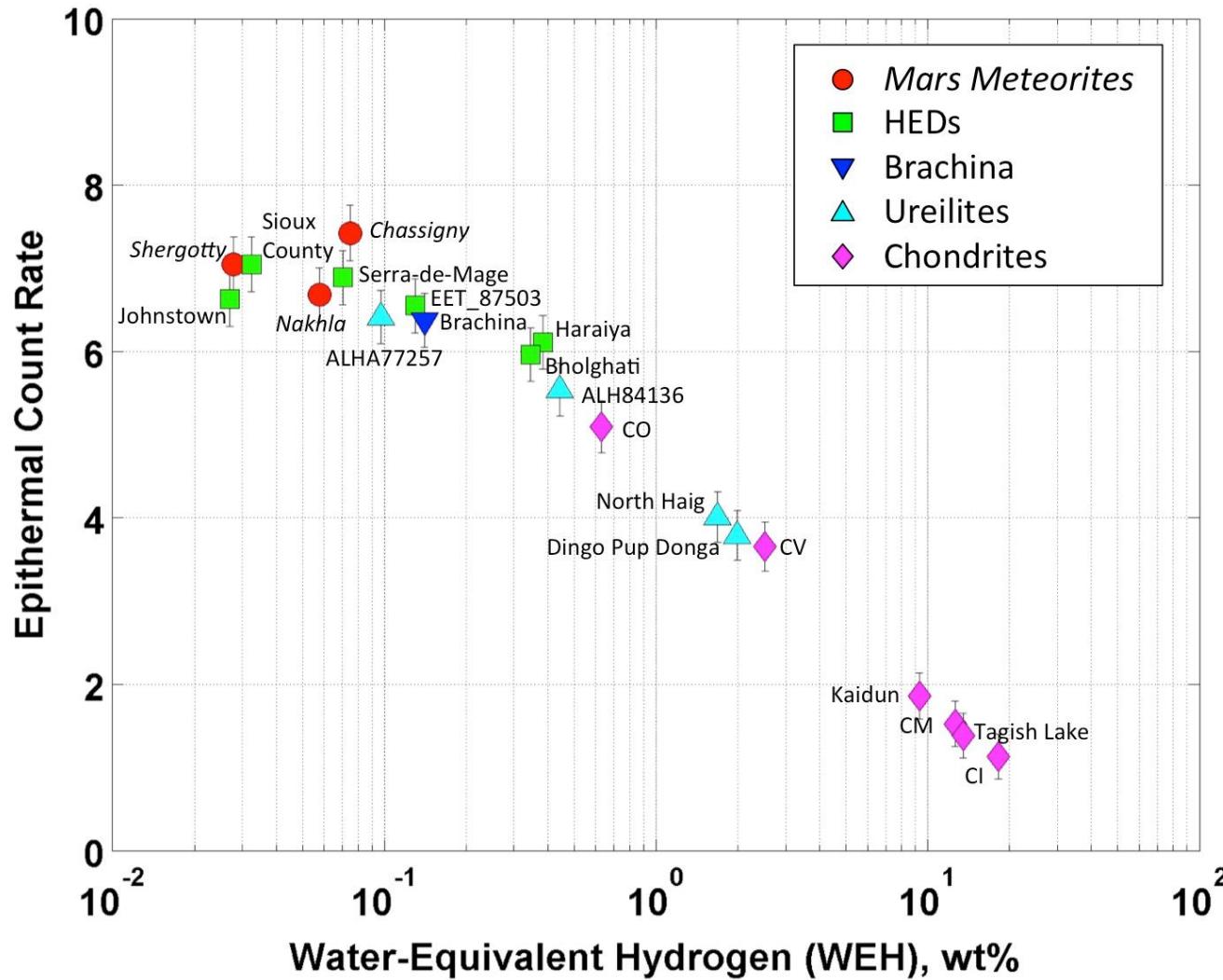
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Will Constrain Deposition of Deimos Dust on Phobos



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Neutron Spectrometry: H Content in Top 1m of Regolith



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H₂O Content in Regolith and Internal Distribution

